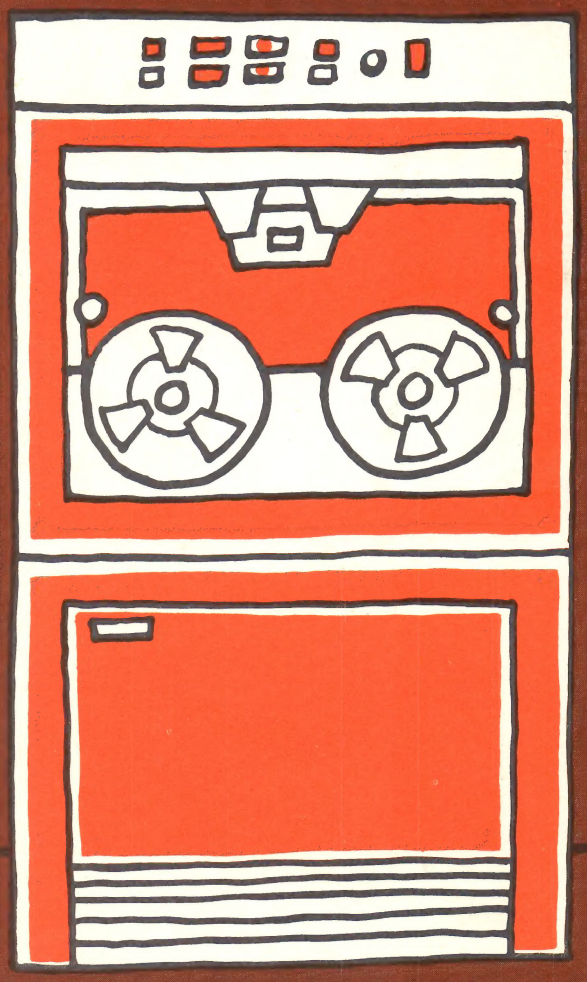
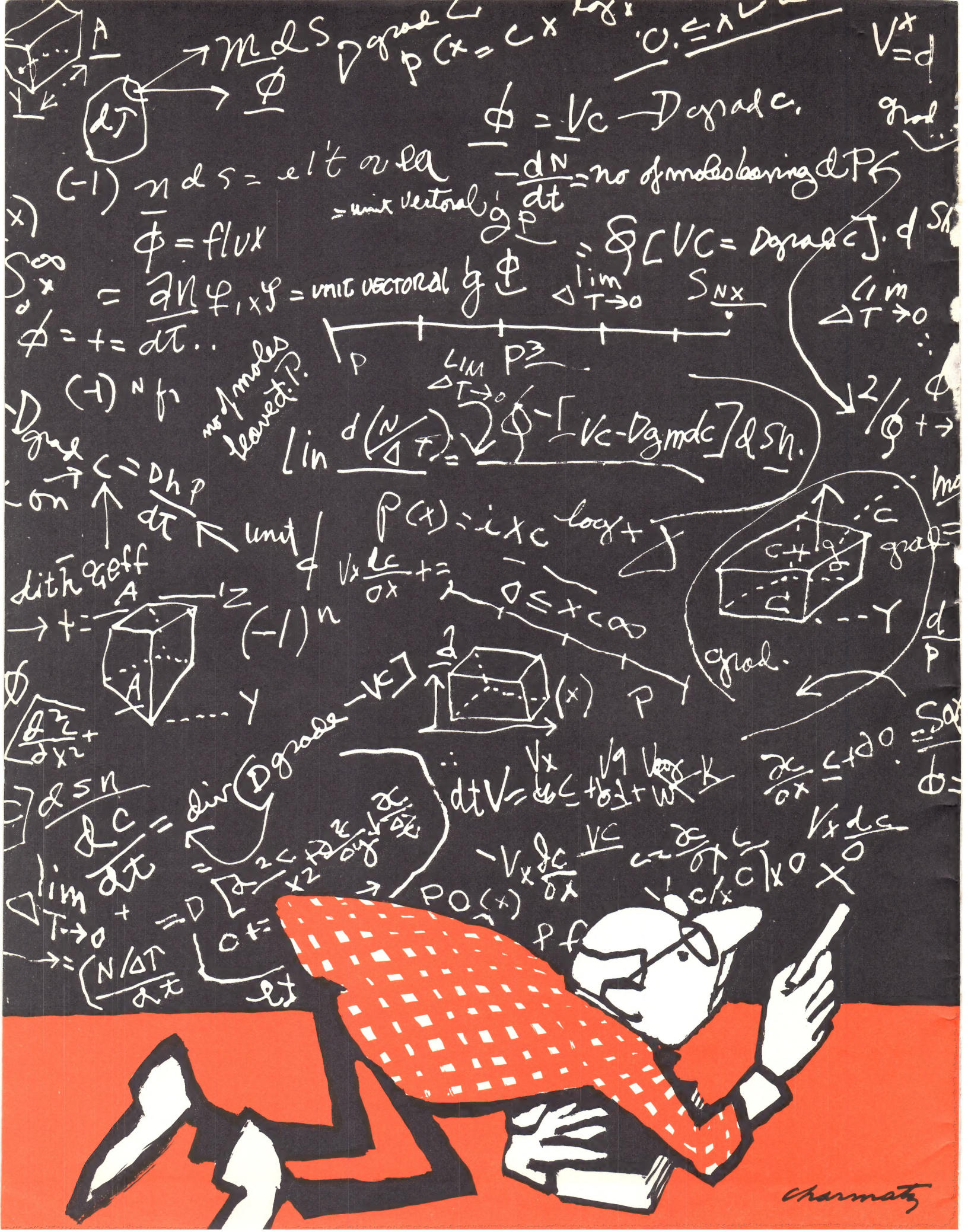
YOU / and the Computer



A STUDENT'S GUIDE

GENERAL ELECTRIC


Φ = Vc − D grad c.
(−1) n ds = el't or lla
= unit vectorial g p
−dN/dt = no of moles leaving dPf
Φ = flux
∂N/∂t = φ, x φ = UNIT VECTORIAL g Φ
Σ [VC = D grad c] · d Sn
no of moles leaved ?
lim ΔT→0 d(N/ΔT) = Σ Φ⁻¹ [Vc − D grad c] d Sn.
P(x) = i x c log x
0 ≤ x < ∞
div (D grad c − Vc)
charmatz

Aron K. Insinga

The computer is a tool that increases your capacity to do intelligent work. It enables you to work problems more quickly, with less drudgery, and with greater accuracy. For example, first year students at the U.S. Military Academy — taught to operate a computer on their second day of class — can solve five tough physics problems in the time it once took to figure out one. Freshmen engineering students at Massachusetts Institute of Technology are now speedily solving advanced road-building problems that formerly were tackled only by seniors.

The computer is extending man's brainpower as the steam engine extended his muscle power. The result is a staggering new capacity to discover, create, build, solve, and think that will affect the way you study, work, and live your everyday life. Without computers, America's space program would not be possible. And, down to earth, computers are helping to eliminate drudgery, expand leisure, and facilitate progress.

One exciting thing about computers is that they are so new. Modern electronic computers weren't invented until after World War II. Yet by 1964 there were over 18,000 computers at work in America, including an estimated 600 in high schools.

Today, computers play a key role in finance, transportation, defense, science, medicine — in practically every industry and profession. They are opening up challenging new careers for young men and women — new careers for high school graduates, as well as for those holding advanced college degrees.

The future clearly belongs to those who understand the computer. And, to a great extent, man's future progress depends on intelligent young people who are able to put the computer to work, solving our social, industrial, and scientific problems. As a major manufacturer of computers, and one of the nation's largest computer users, General Electric hopes that you, the student, will want to play an important role in the computer age — your age.

Computers help man solve complex problems, while eliminating much drudgery of mathematical calculation.

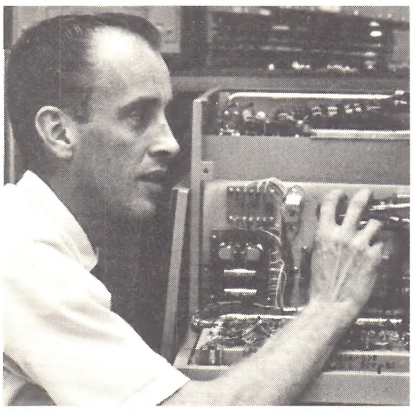
GENERAL ELECTRIC

© by General Electric Company, 1965

Gene Bozarth, 34, heads a group doing computer industrial design.

Dayne Taylor, 24, runs a machine that bends metal for computer cabinets.

Hazel Thompson, 23, welds computer parts while husband finishes college.

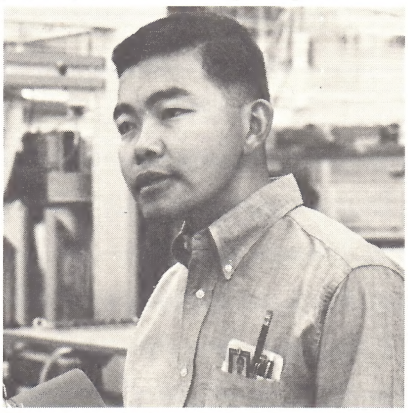


Chuck Strack, 29, engineer working on computer printing equipment.

Ted Hemphill, 22, engineering student employed part-time in computer plant.

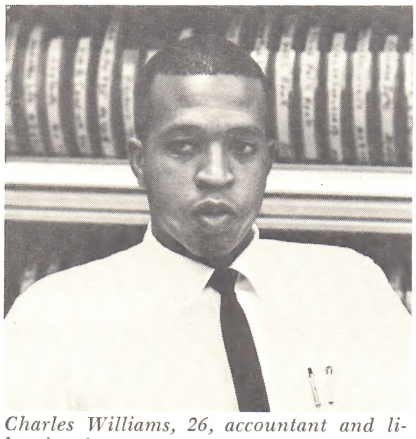
Jackie Brantley, 25, psychology grad who teaches others to use computers.

Helen Ann Patton, 28, has math degree, works as program analyst.

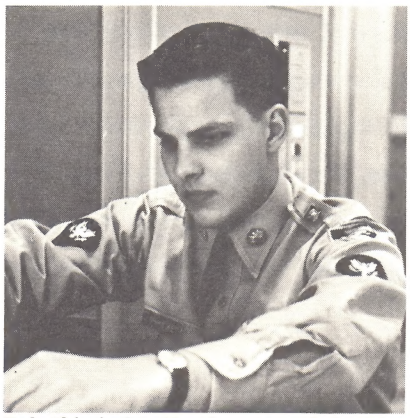


Ying Ong, Jr., 26, tests newly installed computer systems.

Bob Shadburn, 18, learned to operate computers first year at West Point.



Charles Williams, 26, accountant and librarian for computer programs.



Bob Shiminske, 22, plans to seek banking career after Army computer training.

Linda Williamson, 22, helps make wiring boards for computers.

THE COMPUTER AGE

Besides the computers themselves, there are two key elements to the computer age — a complex society with a host of important problems to solve, and people who understand how to put the computer to work to solve these problems. Some people of the computer age — several of them General Electric employees — are pictured on the opposite page.

Each is different — student, soldier, librarian, mathematician. Yet all have something in common. They share the enthusiasm that comes with being in at the beginning of something new and important. Not all computer people, of course, operate computers. Some design them, or write new languages that make the computer easier to use, or figure out systems that enable the computer to solve new types of problems. Others assemble computers, or manufacture their intricate parts, or install or repair them. Together they form a team that promises to bring untold benefits to their fellow men.

The problems of our complex society are many. Among the most important are those caused by a rapidly rising population jamming our hospitals, highways, and schools. College enrollment, for example, is expected to rise nearly 45% between 1965 and 1970, and the number of American families will increase sharply, meaning more bank accounts to keep track of, more insurance to write, more mortgages and loans to process.

If we are to provide useful work for so many people, and provide for their material needs, American industry will have to produce more. But already many industrial processes are becoming too fast and complex for men to control.

Transportation threatens to become chaotic. Our cities need rapid transit systems to move millions of people each hour. But scheduling and operating trains moving at high speeds — only moments apart — require many split-second decisions. These simply can't be made efficiently and safely by men alone.

Similarly, the supersonic passenger airplanes we will soon need — with their millions of parts, miles of wiring, and special heat-resistant metals — pose staggering new design and manufacturing challenges to aeronautical engineers.

To solve these problems and countless others, man needs a new tool. It must be a tool that can perform in a second the computations that would take an individual a lifetime, a tool that can sense when something is wrong — in manufacturing cement or in launching a rocket — and correct it more quickly than a man can blink his eye.

The computer is such a tool. Today, in thousands of offices, plants, and laboratories, it has already started helping man meet the challenges of our complex age. We can group these applications into seven major types of work:

Processing business data. Computers swallow and distill oceans of paper. They balance bank accounts, figure payrolls, check tax returns, update insurance records, keep track of supplies, and send out bills.

Solving mathematical problems. Computers make it possible for researchers and engineers to move ahead quickly to the solution of research, testing, and design problems. For scientists, engineers, and others, the computer eliminates the drudgery of routine problem solving.

Controlling manufacturing plants. Computers have begun to take over complete "on-line" control of certain kinds of processes, including oil refining, electricity generation, and even cookie-baking. Through direct connection to the instruments and controls of the process the computer checks measurements and automatically changes the controls to keep the plant running at the highest possible efficiency. Unlike other computers, process computers, to be most effective, must be designed to fit particular jobs. General Electric, for instance, has designed a type of process computer that withstands the corrosive atmosphere of chemical plants.

Simulation. The computer makes it possible to replace a physical model of a new airplane, a new dam, or a new atomic reactor with a mathematical formula (math model) for testing purposes. In the case of the airplane, for instance, the engineer constructing the math model would take into account all the factors that would determine whether the plane would fly, such as weight, wing span and engine thrust. He would assign number values to each of these factors. By varying the numbers and working out the formula in the computer, he would be able to simulate what the plane would do under a far greater variety of conditions than could ever be simulated by a physical model of the airplane "flown" in a wind tunnel.

Storing and retrieving knowledge. Thanks to the computer, we are beginning to be able to make use of all the valuable information available around the world. Summaries of printed information about steel production or heart disease, for instance, can be compiled, sorted, and stored in the computer and reprinted on a moment's notice. This is being done for scientists, lawyers, and engineers on an increasing scale.

Controlling communication. Our armed forces, government agencies, and large industrial corporations today are increasingly linking their communications facilities, data-collection systems, and computers in complex networks that can route information to offices and plants around the country, process it, and produce up-to-the-minute reports.

Translating languages. The computer is helping us solve one of the greatest barriers to the gathering of information — translation of foreign languages into our own. While this is still in an early stage, before long computers should be able to store vast dictionaries of words and grammar rules and turn out useful translations many times faster than language experts.

THE COMPUTER'S AMAZING CAPACITY

In each of these seven kinds of work, the computer gets the job done far more efficiently than it could possibly be done by man alone. But what's the computer's secret? What makes it such a powerful tool for extending man's brain power? The answer lies in the computer's four special characteristics.

Incredible speed. The computer works one step at a time. These are simple steps that any high school or college student could do. But the difference between the student and the computer is that the computer is able to do a million or more steps in a single second. It can do in a few minutes the same amount of work that you, with pencil and paper, would take years to do. Some GE computers can add 250,000 16-digit numbers in one second.

Permanent memory. The computer can remember both facts and instructions. This stored information can be brought into use in a split second. And, unlike the human memory, the computer never forgets. Think how smart you'd be if you could instantly remember every fact you had ever read or been told.

Great accuracy. Because of its fantastic speed, the computer can solve problems the long and most accurate way. For example, a computer could easily divide 6.1382313290 into 23.5439189113. By contrast, most people, working the problem by hand, would probably settle for dividing 6.1 into 23.5.

Works automatically. The computer has two abilities that together enable it to work automatically: It can remember a set of instructions, and it can execute these instructions in sequence without human direction. If you were a computer operator, for instance, you could feed instructions into the computer, then go have lunch. The computer would work automatically, step by step, figuring a solution to your problem.

COMPUTERS ON THE JOB

Writing cake mix recipes. Pillsbury Company uses a GE computer to figure out the best combination of available ingredients to meet nutritional requirements. Determining the proper formula takes about 40 seconds as opposed to the four to five hours formerly required by a nutrition expert with a desk calculator.

Running San Francisco's Rapid Transit System. Passenger trains, only 90 seconds apart, will zip along at 80 miles an hour when San Francisco's rapid transit system begins operation. A computer will keep the entire system on schedule.

Helping lawyers. The University of Pittsburgh is putting on computer tape all the laws of Pennsylvania, New York, and New Jersey, plus Fedederal tax regulations. In a recent test the computer was pitted against two law clerks to find all sections of the tax code containing the words "dividends received." The two clerks spent two days and found only 17 sections. The computer spent one hour and found all 21 sections.

Catching income tax cheats. By 1966 all income tax returns will be checked by computer. Stored on 400 miles of magnetic tape will be the information on what each American earns from all sources of income.

Charting a hurricane. Weather watchers at Miami have pressed the computer into service to provide quicker forecasts of a storm's possible course. Out of 100,000 readings in a single day, recorded and sorted by computers, the storm experts are also trying to learn the peculiar ways of hurricanes—how they gather and finally break up.

Mixing cement. The California Portland Cement Company, mixes cement on a continual basis, thanks to a GE computer. The computer uses an X-ray analyzer to check amounts of sand, gravel, and other materials going into the cement, and according to the readings, it alters the flow of materials to make a perfect mix.

Diagnosing a disease. A computer system at Massachusetts Institute of Technology can process and analyze information from electrocardiograms and other diagnostic measures, and then return the data by telephone to three Boston hospitals. In the near future the system will be expanded to include remote diagnosis for hospitals all over New England.

Taming the Arkansas River. Army Engineers are using computers to design a flood control and navigation project for the Arkansas and Red Rivers. The computer — considering thousands of weather and current variables — performs in days design calculations that would take months by conventional methods.

THE COMPUTER WORKS THE SAME WAY YOU DO

How does the computer solve a problem? In very much the same way that you do.

Let's take a problem. You're paymaster of the Supersonic Hubcap Company. You want to figure out how much to pay one employee, George Geargrinder, for last week's work. You ask your secretary to check the pay records and bring you certain information: how many hours Mr. Geargrinder worked last week, how much he earns an hour, and his payroll deductions. She checks the records and reports that Mr. Geargrinder worked 35 hours. His rate of pay is $3 an hour. His deductions are 15% for income tax and $1 for insurance.

With these facts you can easily figure out George Geargrinder's wages. First, find gross pay by multiplying the hours he worked by his rate of pay. This comes to $105. Now figure the deductions: income tax is 15% of $105, or $15.75; add $1 for health insurance and you get a total of $16.75. Subtract these deductions from $105 gross pay, and you end up with $88.25, which is Mr. Geargrinder's take-home pay. Write him a check for this amount.

In working this problem you performed five main functions. The computer performs the same five functions. They are:

A. Input. This is getting the facts in hand so you can use them. Your secretary performed an input function when she gave you Mr. Geargrinder's pay records. With a computer, you also feed in basic information so it can work the problem.

B. Storage. This is keeping the pertinent information available for ready use in working a problem. The computer has a memory in which it stores both information for solving a problem and instructions on how to use the information.

C. Calculation. You solved this problem with an adding machine; you might have used a pencil and paper. The computer's calculating, or arithmetic, unit operates on the same principles as an adding machine. It can add, subtract, multiply, and divide.

D. Output. After you gathered your facts and worked the necessary arithmetic, you had the answer. George Geargrinder was due $88.25 in wages, so you wrote him a check. This was output. For the computer, output is the act of taking answers out of the computer after the problem has been worked.

E. Control. Control simply means doing things in proper order. When you work a problem, you subconsciously do first things first: look at records, find hours worked, write on paper, and so forth. The computer must be guided every step of the way. This is the job of the computer's control unit.

Obviously you don't need a computer if your only job is to figure out one man's wages. But suppose as paymaster of Supersonic Hubcap Company you have to figure out the wages for 10,000 employees! For this you need the help of a computer. For a computer, working automatically, can calculate the wages and write paychecks for 10,000 persons in a single day.

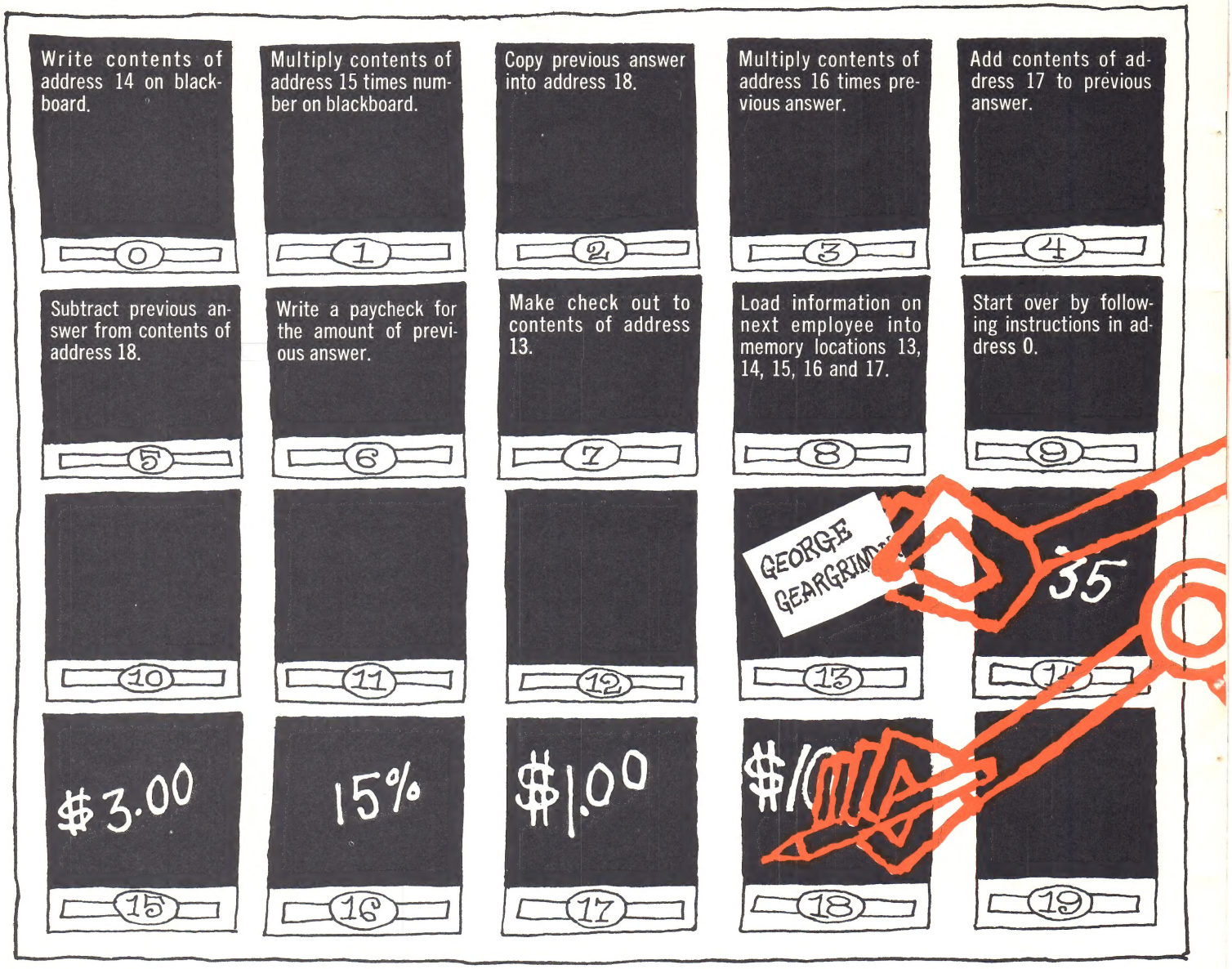
"BASIC" COMPUTER AT WORK

The heart of the computer's ability to work automatically is its ability to remember instructions as well as facts.

The computer's memory can be compared to a block of post-office boxes, where each box holds one person's mail. In the computer's memory each "box" holds one item of information, either a fact or an instruction. In the computer these "boxes" are called memory locations.

With some post-office boxes as the memory, a blackboard as the calculating section, and a mechanical hand to control the movement of data and instructions, we have a basic computer.

Let's see if we can have our com-



puter calculate the wages of Supersonic Hubcap Company's 10,000 employees and issue their checks.

First, we need input, which in this case is payroll facts. Previously prepared time cards —one for each employee — will provide such facts. We place these cards in an input machine that loads payroll facts on one employee at a time into the computer's memory.

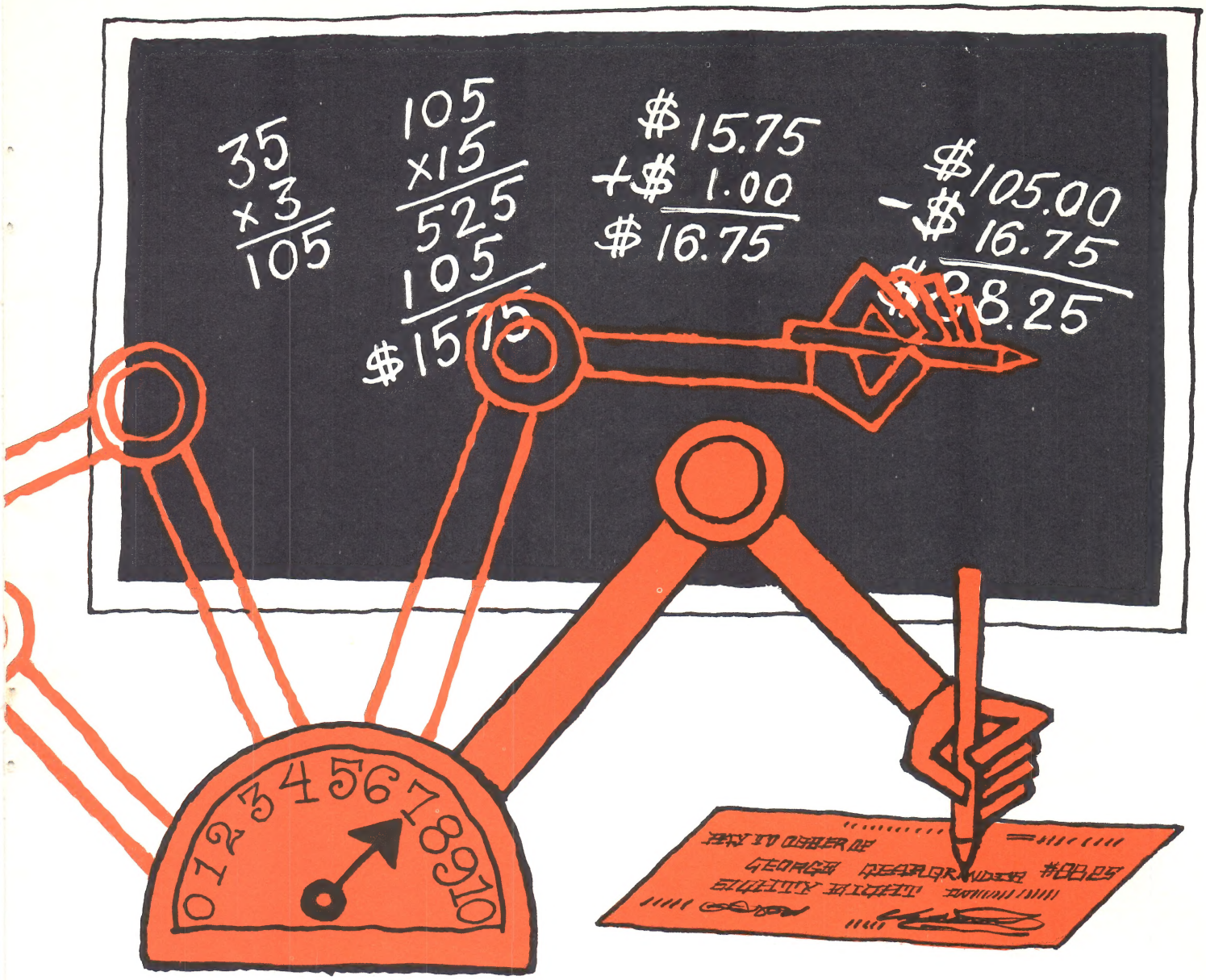
We must decide in which memory locations to store each fact. Each memory location has its own identifying number called an address. Let's put the employee's name in address 13; hours worked in address 14; rate of pay in address 15; percentage of income tax deduction in address 16, and health insurance deduction in address 17.

(In the boxes illustrated above we have used George Geargrinder's pay information — 35 hours worked, $3 an hour, 15% tax deduction, and $1 for health insurance.)

Now we can write a series of instructions that will automatically figure the pay of George Geargrinder, or any other person whose pay facts are loaded into the computer.

We will store the instructions in the computer's memory in exactly the same way we stored the pay facts. It doesn't make any difference which boxes we use, as all are equally accessible. Let's put the first instruction in box number 0.

Address	Instruction
0	Write contents of address 14 (hours worked) on blackboard.
1	Multiply contents of address 15 (rate of pay) times number on blackboard.
2	Copy previous answer into address 18 (but don't erase it from blackboard).
3	Multiply contents of address 16 (percentage of income tax deduction) times previous answer.
4	Add contents of address 17 to previous answer.
5	Subtract previous answer from contents of address 18 (gross pay).

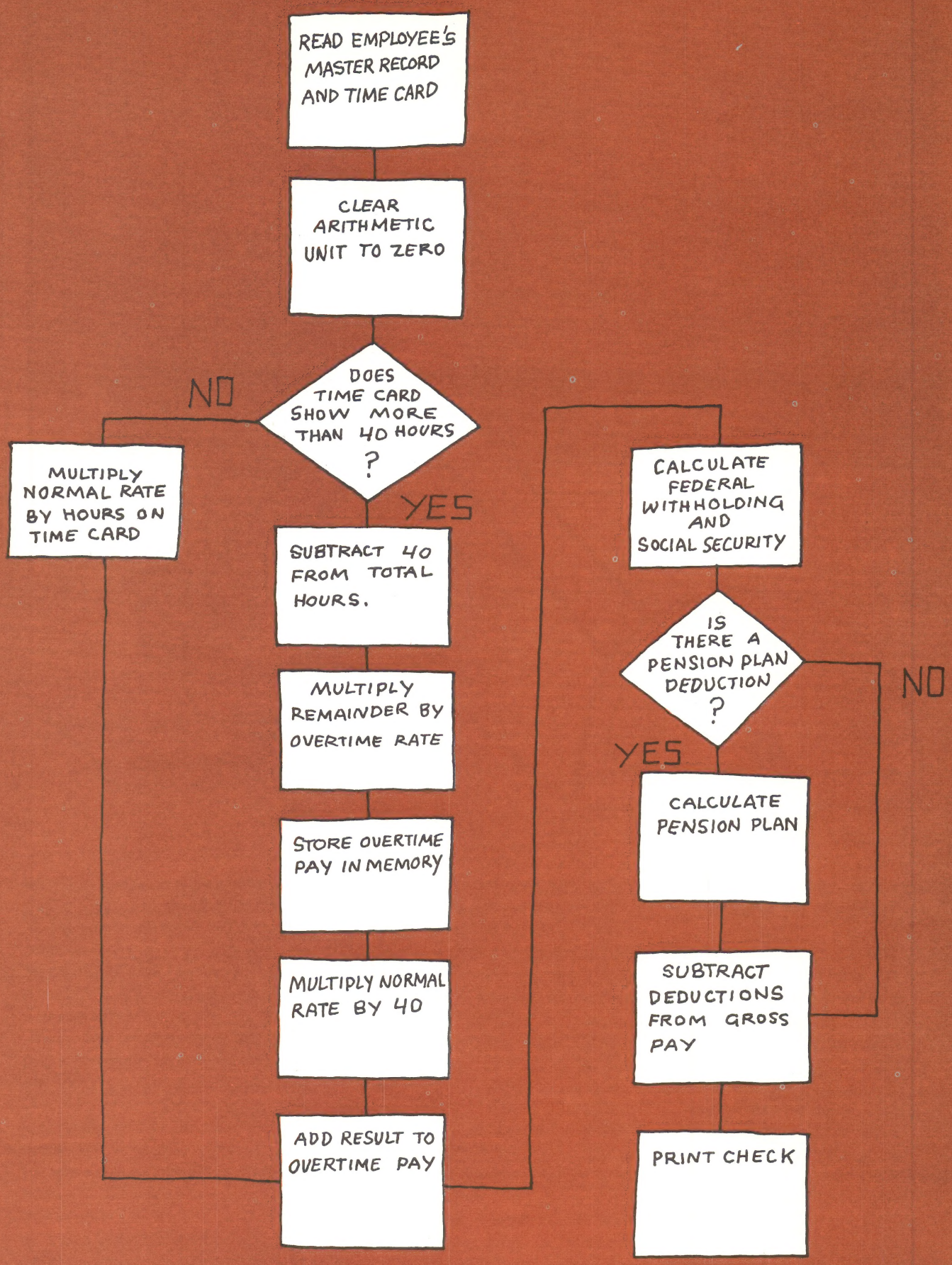


- (6) Write a paycheck for the amount of previous answer.
- (7) Make check out to contents of address 13 (name of employee).
- (8) Load information about next employee into memory locations 13, 14, 15, 16 and 17. (Loading new data into memory automatically erases information previously there.)
- (9) Start over by following instructions in address 0.

To get our computer started on the payroll, we can "set" it at address number 0, just as we might set the hands of a clock. After following the instruction in address 0, the computer will automatically move forward, one address at a time, carrying out each instruction as it goes. The last instruction – stored in address 9 – resets the computer at address 0, thus automatically starting the operation all over again.

A real computer doesn't have mechanical hands. Instead it has electronic connections that carry information at nearly the speed of light (186,000 miles per second). Thus, you can see how the computer could easily figure out a payroll thousands of times faster than you could, working by hand.

When all 10,000 employees have been paid, we remove payroll instructions from the computer's memory and store them for future use in coded form on cards or tape. Then we can put in a different set of instructions and do a different job. For instance, we might put in a program that decides how many hubcaps we should manufacture in the next month. Along with this new program, we would put into the computer all the required data – sales reports from regional offices, number of hubcaps already on hand, etc. –and start the machine. In the same methodical, step-by-step way, the computer would come up with the month's manufacturing requirements.


READ EMPLOYEE'S MASTER RECORD AND TIME CARD
CLEAR ARITHMETIC UNIT TO ZERO
DOES TIME CARD SHOW MORE THAN 40 HOURS ?
NO
YES
MULTIPLY NORMAL RATE BY HOURS ON TIME CARD
SUBTRACT 40 FROM TOTAL HOURS.
MULTIPLY REMAINDER BY OVERTIME RATE
STORE OVERTIME PAY IN MEMORY
MULTIPLY NORMAL RATE BY 40
ADD RESULT TO OVERTIME PAY
CALCULATE FEDERAL WITHHOLDING AND SOCIAL SECURITY
IS THERE A PENSION PLAN DEDUCTION ?
YES
NO
CALCULATE PENSION PLAN
SUBTRACT DEDUCTIONS FROM GROSS PAY
PRINT CHECK

PROGRAMMING

In solving any kind of problem, a computer is helpless until it has been given a detailed set of instructions. The computer can't figure out how to solve the problem. All it can do is slavishly follow directions step by step until the job is completed. This is true for any problem we try to solve with a computer, whether it's simply adding a column of numbers, or solving the complicated equations necessary to send a missile to the moon. These detailed instructions are called the computer program.

To write a program, we must first understand the problem to be solved. We must analyze it, and break it down into its components.

One way to do this is to construct a flow chart of the problem. This is a line diagram that shows each part of the total problem and its logical relationship to every other part. The flow chart is similar to the diagram of a pass play that a football coach draws on the blackboard, or to a pattern for making a dress. It shows component parts of the problem just as a play diagram indicates each blocking assignment. And, it shows how all the parts fit together just as the pattern indicates where two pieces of cloth are to be sewn together.

To work in the computer, each part of the flow chart must be broken down into simple instructions. One part of the flow chart might require 20 or more individual steps in the computer.

The flow chart illustrated at the left shows the steps in a payroll program that is slightly more complicated than the payroll program example on the previous page. The boxes represent work to be done, and the diamonds choices to be made.

This program can figure out the pay for employees who work overtime. In the third step the program asks, "Does time card show more than 40 hours?" If the answer is "yes," the program flows forward and works a series of instructions that calculate overtime pay. If the answer is "no," the program skips these instructions and goes on to figure pay at the regular rate.

This action of skipping part of the program, or of choosing which of two sets of instructions to follow, is called branching. It's an operation much like our own logical powers. In a football play, for example, the halfback may be given two assignments. If the opposing linebacker rushes in, the halfback blocks him. If the linebacker drops back the halfback moves out a short distance to the side and becomes a pass receiver. What the halfback does follows logically from what the opposing linebacker does.

It's the same way with branching. The computer decides which of two sets of instructions to follow by asking whether the hours worked are greater than 40. It makes a simple "yes-no" decision.

In very complex problems where there are thousands of variables, there might be thousands of such choices. The computer would take them one at a time, make a simple "yes-no" decision, and switch to the appropriate instructions.

Because it can make decisions, we say the computer has a logical capability. But it's important to realize that even in making these decisions, the computer is simply following instructions. It is the man or woman writing the program who decides when a decision is needed, and what factors will determine which choice is taken.

Sometimes programs have "bugs" — computer talk for errors. If you don't "de-bug" before running a program you'll get "garbage."

Once the problem has been mapped out in a flow chart, and broken down into individual simple operations, we must write the instructions telling the computer how to handle each operation. But here we run into another problem. The computer doesn't understand English. So, we have to write our instructions in a language, or code, that the computer understands.

This is a flow chart. Writing a problem out step by step is essential in preparing computer instructions.

THE BINARY CODE

The computer's language is written in binary code. It is a simple way of communicating, once you get the hang of it. Third and fourth grade children in many parts of the country are learning binary as part of "New Math."

If you already understand binary, you know that there are really just two new ideas that must be grasped:

First, whereas decimal numbers — the kind of numbers we ordinarily use — are built on a base of 10, binary numbers are on a base of 2. The base 10 means that when you move a digit one space to the left (and add a zero), it's worth 10 times as much. Another way of saying this is that it increases by the power of 10. With binary numbers, using a base of two, every time you move a number to the left, it's worth 2 times as much, or it increases by the power of 2.

Just as in the decimal system, based on the power of ten, the value increases from right to left, so do values in the binary system increase from right to left by the value of the base. By way of illustration:

Decimal: 1,000 - 100 - 10 - 1
Binary: 32 - 16 - 8 - 4 - 2 - 1

The second thing to learn about binary is that the system uses only two numbers: 1 and 0. In other words, you must forget about the numbers 2, 3, 4, 5, 6, 7, 8, and 9. They are never used in the binary system.

So the question arises, how do you count to two, without a 2? It's simple. As we noted, the value of the binary number increases by two times as you move it one space to the left. To get two in binary then, you simply move your 1 one space to the left and add zero. Thus, 10 in binary is the same as 2 in decimal.

To visualize this imagine two cars — one has a mileage indicator in the regular decimal system, the other has a mileage indicator in the binary system. At the start of a race, mileage indicators on each car read: 00000. Now watch what happens as they go down the road:

Binary		Decimal
00000	start	00000
00001	first mile	00001
00010	second mile	00002
00011	third mile	00003
00100	fourth mile	00004
00101	fifth mile	00005
00110	sixth mile	00006
00111	seventh mile	00007
01000	eighth mile	00008
01001	ninth mile	00009
01010	tenth mile	00010
01011	eleventh mile	00011
01100	twelfth mile	00012
01101	thirteenth mile	00013
01110	fourteenth mile	00014
01111	fifteenth mile	00015
10000	sixteenth mile	00016
_____	seventeenth mile	00017
_____	eighteenth mile	00018
_____	nineteenth mile	00019
_____	twentieth mile	00020
_____	twenty-first mile	00021
_____	twenty-second mile	00022
_____	twenty-third mile	00023
_____	twenty-fourth mile	00024
11001	twenty-fifth mile	00025

(Fill in the blanks in the binary column.)

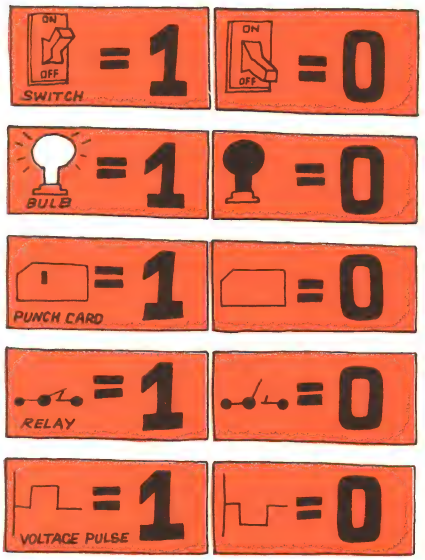
There is an easy way to convert a binary number to decimal. Just write down the successive powers of 2, then underneath match up the binary number. Take binary number 1100101:

64	32	16	8	4	2	1
1	1	0	0	1	0	1

64 + 32 + 4 + 1 = 101

Each digit — either a 1 or a 0 — in a binary number is called a bit (short for binary digit). This is important to remember because, as we will see, information moves through a computer a bit at a time.

While the binary code may seem a bit awkward to those who are used to the decimal system, it is simplicity itself to the computer. This is because the basic electronic parts inside the computer can exist in only two possible states: current is on or off, a switch is open or closed, magnetic materials are magnetized in one direction or the opposite. At right are some examples:



SYMBOLIC LANGUAGES

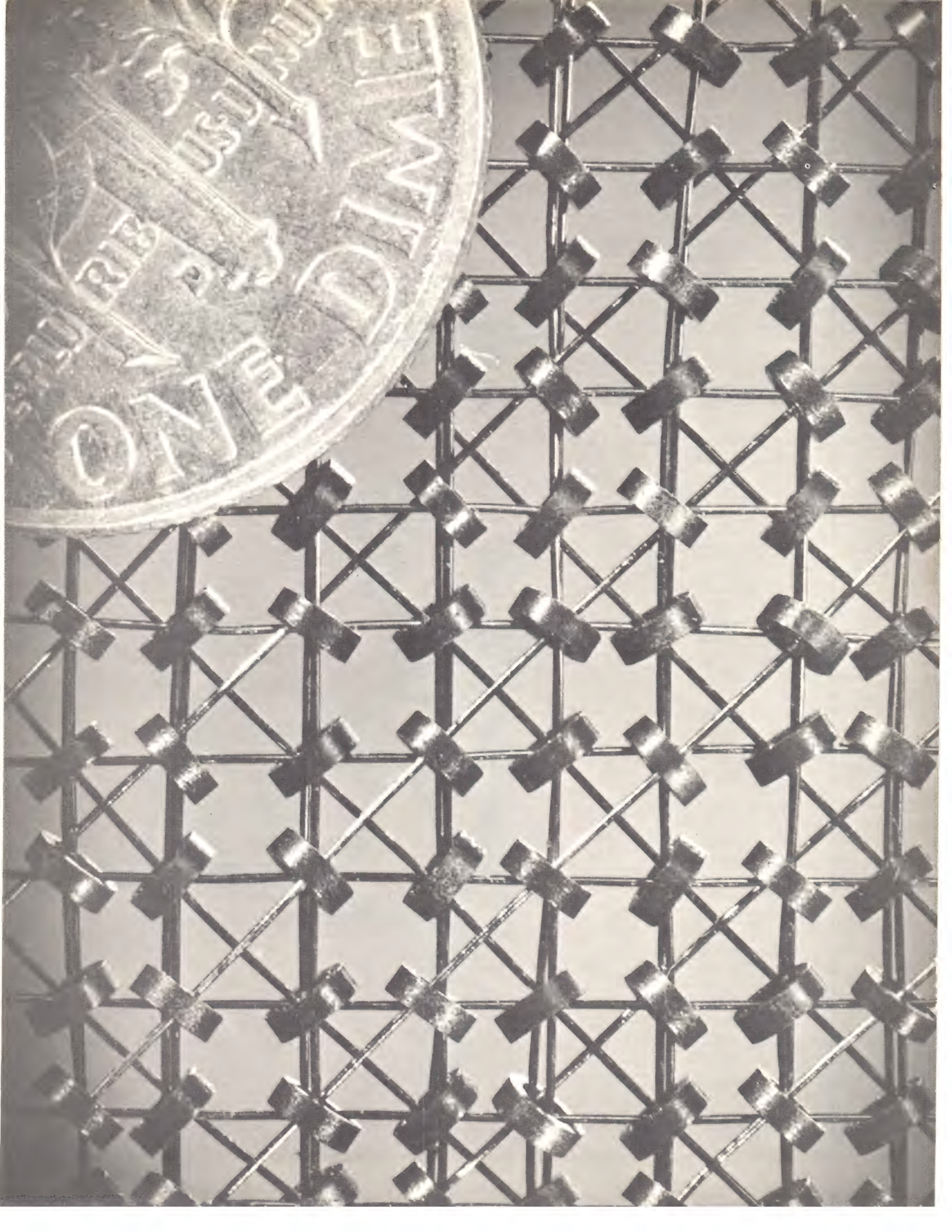
You must understand binary before you can learn how a computer really works. However, thanks to new short-cut methods — called symbolic languages — you no longer use the binary code yourself when you talk with a computer. There's nothing hard about symbolic languages. Most of us hear some kind of symbolic language every day.

Have you ever walked into a restaurant and asked for a glass of milk, only to have the waitress call for "one cow," or translate someone's request for a bacon, lettuce and tomato sandwich on toast into, "BLT down."

Restaurant workers talk to each other in a special code because it is short and precise. Computer programmers use special codes for the same reasons, and because they make it very easy to use the computer. Until a few years ago, if you wanted a computer to add something, you might have typed an instruction like this: 1011010111010001. Today, you can merely type in the symbol for "add," and the computer will automatically translate "add" into the correct binary instruction.

Today almost anyone can quickly learn to use a computer, thanks to symbolic language. In an hour West Point cadets learn enough of their special POINTRAN language to operate a computer. Other special languages, such as FORTRAN, COBOL and ALGOL, make it easy for businessmen, scientists, and engineers to write programs, using words and symbols they are used to.

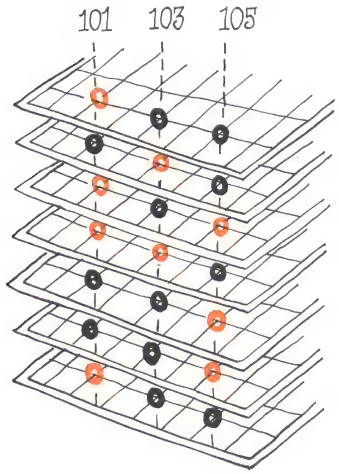
After a program is written in symbolic language, it is automatically translated into binary code, known as "machine language." The computer can automatically do this because somebody previously had written a special program — called an assembler — that converts other people's symbolic programs into machine language. Once the symbolic program has been converted to binary, it can move as electronic pulses into the computer's memory.


ONE DIME

COMPUTER MEMORY

When information has been translated by the computer into binary language, the computer is ready to store it in its memory. There are several kinds of memory devices used in computers, but most of today's high-speed machines use magnetic cores. These are tiny little "doughnuts" the size of pinheads which are made of a special ferromagnetic ceramic material. Each core can at any time be magnetized in either of two directions. One direction stands for a binary 0, the other direction for a binary 1. By arranging these cores in a column, we can store any binary number. We simply charge the individual cores in one of two directions, representing either a 1 or a 0. The column of these cores then stands for a binary number. Such a number, in turn, can represent any kind of information – from an automobile part number to a person (people are frequently known to computers by their Social Security numbers). In the illustration below the orange cores stand for 1, and the black cores stand for 0.

Each one of the columns is assigned an address and can store either one fact or one instruction. When we tell the computer to read the contents of address 101, it will read each of the cores in the column designated 101, moving the bits of information in the form of electronic pulses to whatever location we designate, such as to the arithmetic unit. In the memory unit below, address 101 holds the number 77 in binary. Can you tell what numbers are stored in addresses 103 and 105?



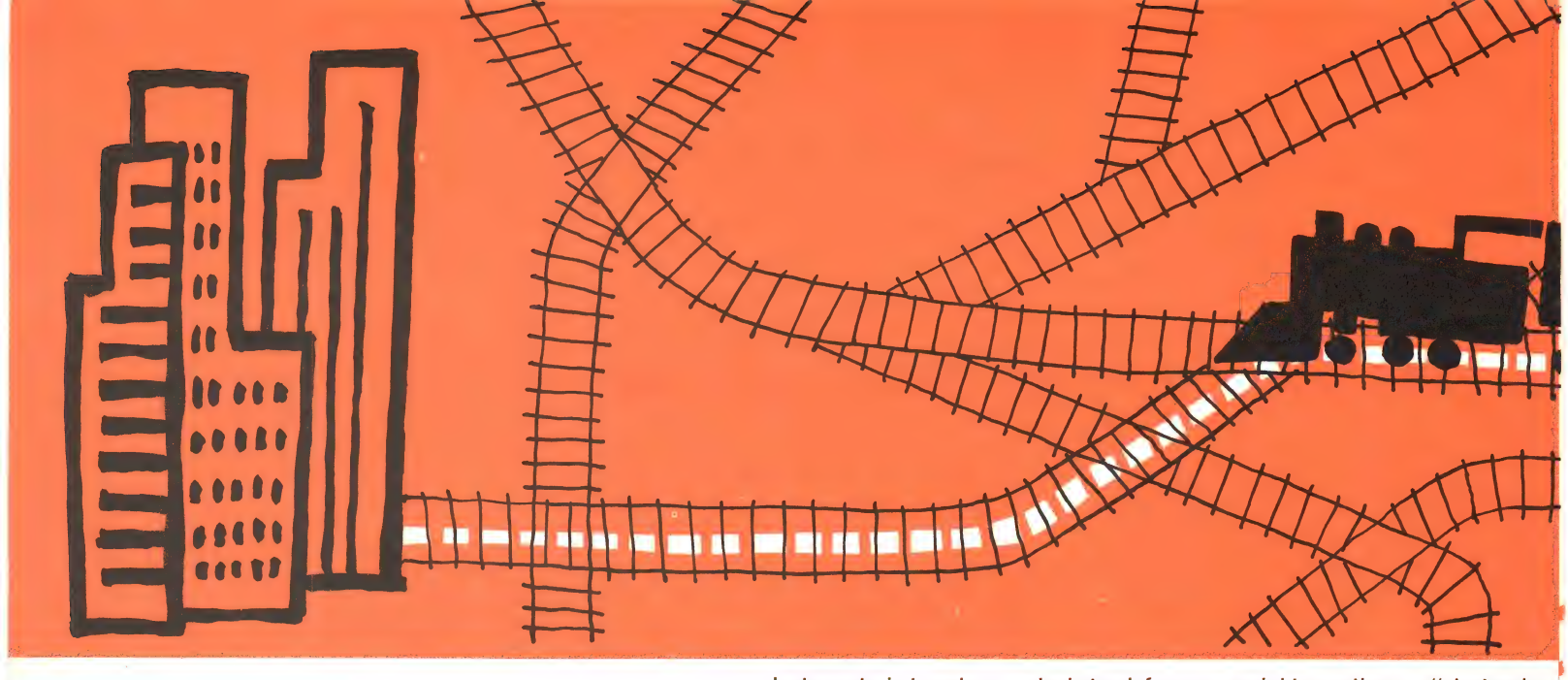
Tiny magnetic cores — far smaller than a dime — are the heart of a computer's memory. Each core can remember one bit (a 1 or a 0) of information.

Thousands of these tiny ferrite doughnuts are strung on crisscrossed wires inside a frame that looks something like a square tennis racket. The frames are stacked up one on top of the other to make a basic memory unit. In General Electric's GE-625 computer a basic memory unit, which is five inches by five inches by three inches in size, holds more than 150,000 tiny ferrite cores.

Therefore, one unit can store over 150,000 bits of information in a form representing 1's or 0's. These computers can hold a variable number of memory units. Normally they hold 18 basic memory units with a total of some 2,700,000 magnetic cores, each able to store one bit of information.

But no matter how many cores a computer may hold in its memory, the principle remains the same. The cores are held in basic memory units, with columns of cores arranged as a unit with an address. The cores under each address are connected separately to the computer's control section. Information can be stored in each address by magnetizing the cores in one direction or the other so that they represent binary numbers. Information can instantly be "read out" of any address and used in working problems. If desired, information can be erased from any address and replaced with new information.

There are other kinds of memory devices. We can use stacks of discs that look like phonograph records. These play back coded information in much the same way that a phonograph record plays back music. Or, we can use thin film memory units that hold rows of magnetic charges. But in any case, we are still doing the same basic thing. We are converting information into a series of magnetic charges, and storing these charges.



Just as a train travels on a single track from one point to another, so "electronic

THE COMPUTER IN OPERATION

We now see how an electronic machine can remember facts and instructions. And we know it has a built-in arithmetic unit that works something like a desk-top adding machine, only much faster. But there's one more important step to understanding the computer. How does information get from the memory to the arithmetic unit? There may be millions of numbers stored in the computer's memory. When we say "Add the contents of address 101," how does the computer find this particular address? And how is the information stored in the memory cores actually moved into the arithmetic unit?

Inside the computer are thousands of wires connecting the different parts of the computer, just as railroad tracks crisscross our country, connecting every city with every other. Also within the computer are thousands of switches that can be opened or closed to form a direct line between two specific parts of the machine. If you boarded a train in New York and traveled to Chicago, hundreds of railroad switches would move, setting up a direct line of track between the two cities. Out of the millions of miles of track in the country, the switches would set one route for the train.

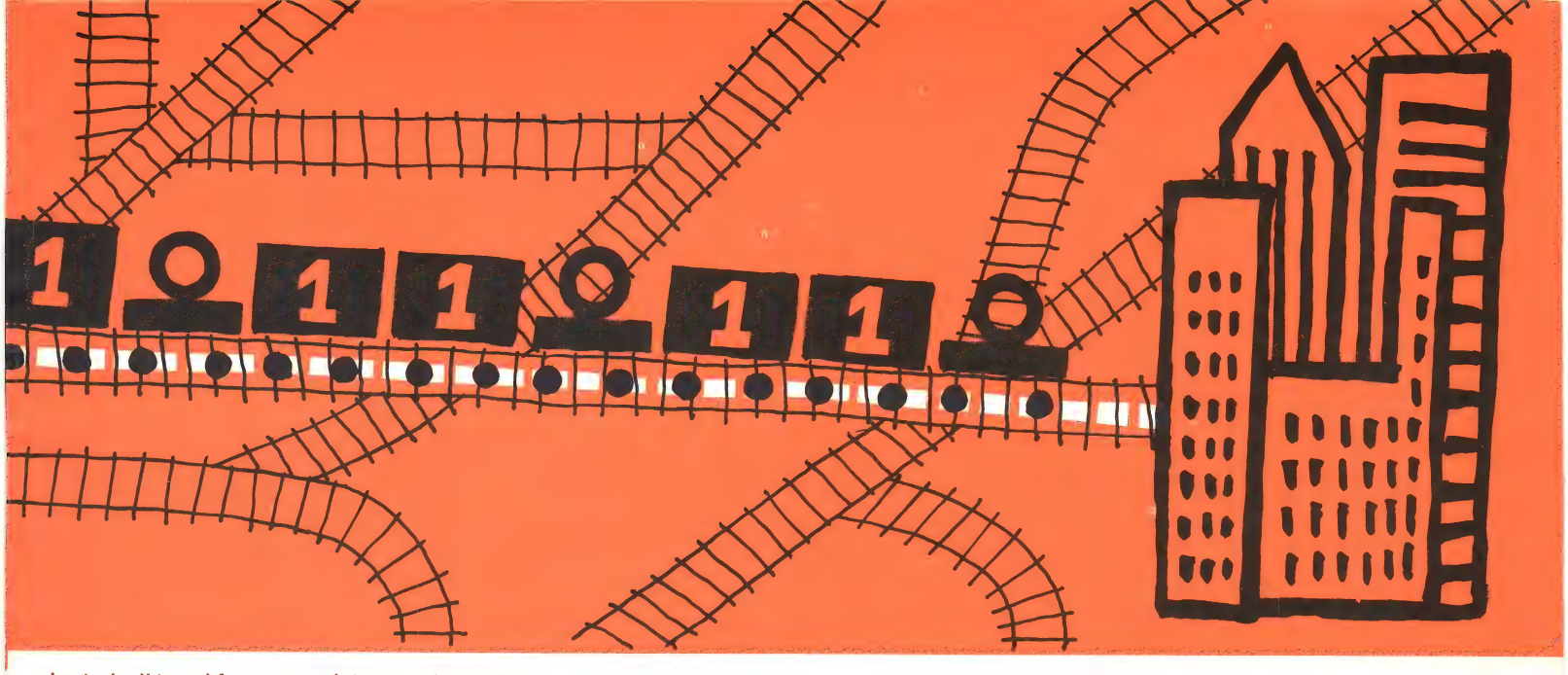
The computer works the same way. When it finds an instruction that says, "Add the contents of address 101," switches move to set up a direct line between address 101 and the electronic adding machine. When the line is open electronic pulses, each representing one bit of information, move from the memory location to the arithmetic unit. Because these pulses move one after another, they are sometimes called a pulse train.

Think of a simple telephone call. When you want to reach someone in another city you dial a number. The dial converts the number into a series of electronic pulses. These pulses move a set of switches called relays, which set up a direct line between the two telephones. Although the telephone system consists of millions of telephones, and billions of interconnected wires, when you call there is a connection established between just two points—you and the person you're calling.

The completed connections are called circuits. In the computer different circuits do many kinds of work. They may move numbers out of an address in the computer's memory and deposit them in the arithmetic section of the computer. Then, another series of circuits will cause addition to take place. Finally, circuits may send information out of the computer, perhaps by recording it on magnetic tape.

The computer operates on a series of electronic pulses. The pulses travel through the machine rhythmically at a rate of up to one billion pulses a second. Each pulse opens and closes a series of switches setting up one complete circuit—perhaps moving a binary signal from one place to another, or perhaps carrying out an addition in the arithmetic section. It's the ability of these electronic switches to open and close so rapidly that gives the computer its fantastic speed.

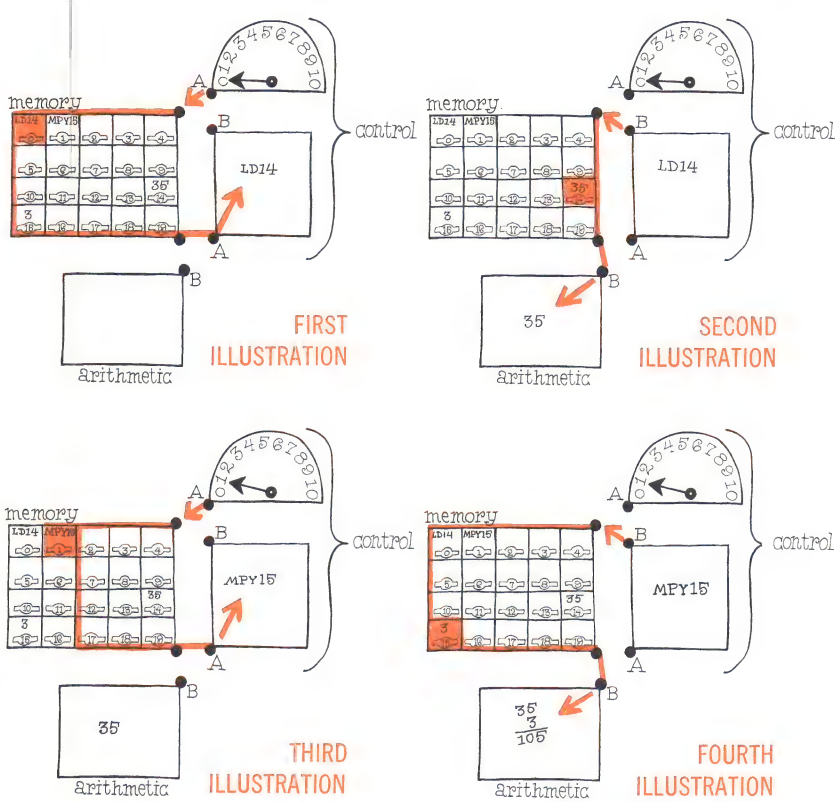
While the computer itself—operating as it does without moving parts—is incredibly fast, the mechanical devices for getting information in and out of the computer are much less speedy.



pulse trains" travel from one point to another, within a computer system.

HOW COMPUTER CIRCUITS WORK

The four illustrations below show how a computer might follow a segment of a payroll program — to find gross pay. This is part of the same program that operated the "basic" computer on pages 6 and 7. Only now we see how a computer really operates — not with a mechanical arm, but with switches that establish different circuits which route information from one place to another.



First illustration. The computer operator may start things going by directing the computer to read instruction 0. This causes switches to move to the A position connecting memory location 0 with control. The instruction in location 0 moves into the control unit.

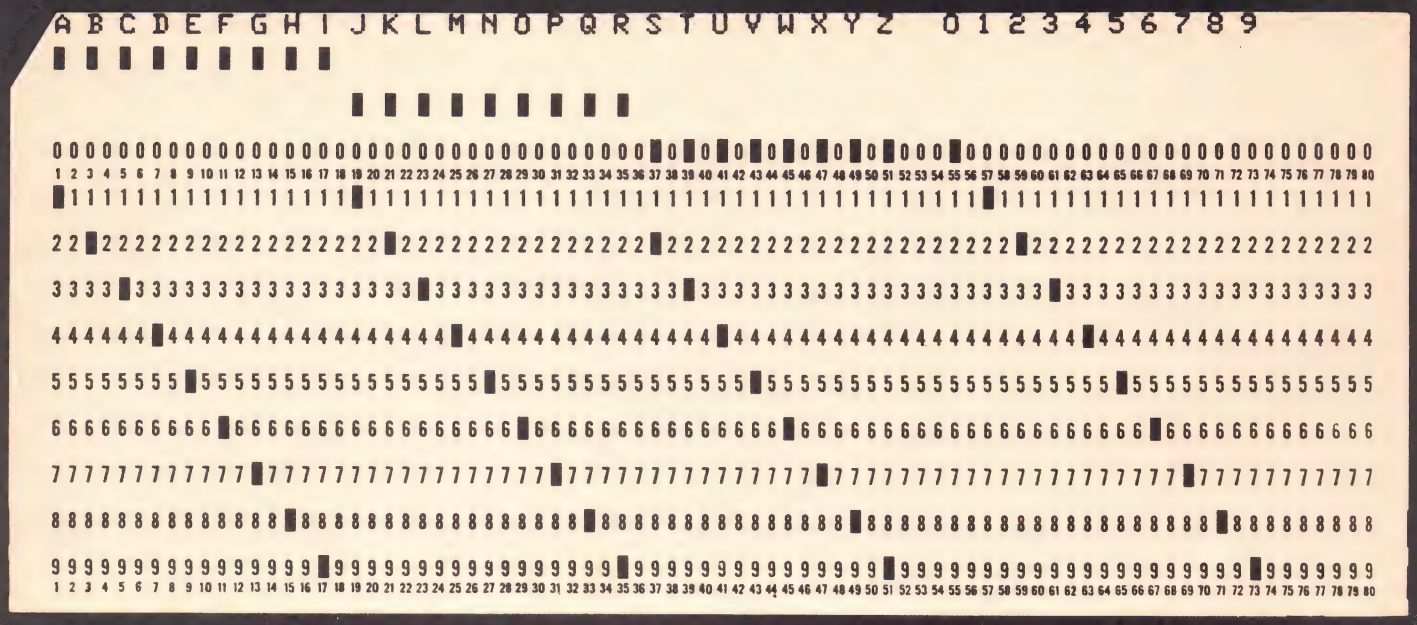
Second illustration. The computer now acts on this instruction. The instruction (LD 14) tells the computer to move contents of memory location 14 to the arithmetic unit. The instruction causes switches to move to the B position connecting memory location 14 to the arithmetic unit. The figure 35, stored in this location and representing hours worked, then flows into the arithmetic unit. This completes instruction 0.

Third illustration. Switches again return to the A position. The computer control now automatically moves to instruction 1. The instruction in memory location 1 moves into the control unit.

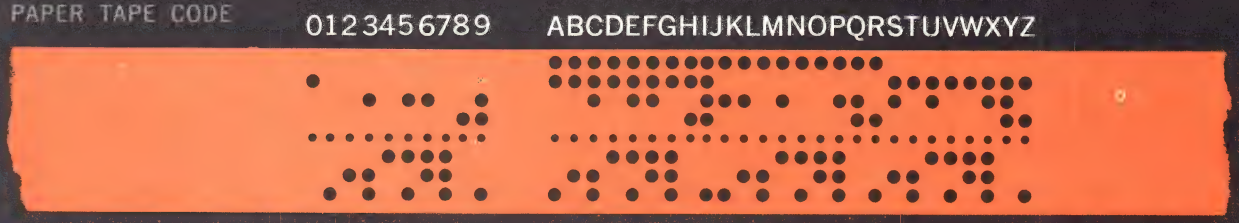
Fourth illustration. The computer now acts on this new instruction (MPY 15) which tells it to multiply the value already in the arithmetic unit by the value in memory location 15. To do this, switches move back to the B position connecting memory location 15 with the arithmetic unit. The figure 3, stored in this location and representing dollars earned per hour, flows into the arithmetic unit and is multiplied by the figure 35, producing the figure for gross pay.

When you recall that in a real computer switches can in effect move between A and b a billion times a second, you can begin to comprehend the computer's fantastic speed.

PUNCHED CARD WITH HOLLERITH CODE

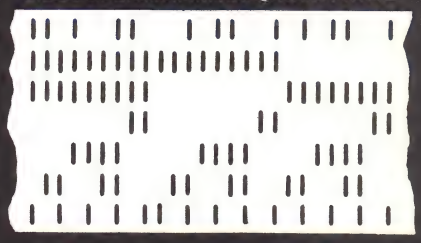


PAPER TAPE CODE

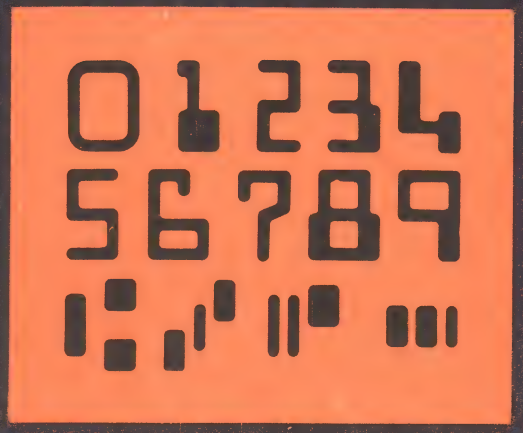


MAGNETIC TAPE — ACTUAL SIZE

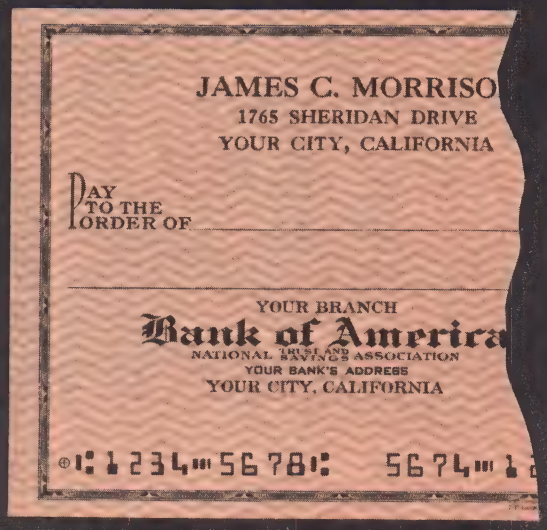
MAGNETIC TAPE CODE



MAGNETIC INK CHARACTERS



CODED PERSONAL CHECK



HOW YOU TALK TO A COMPUTER

Just as you have various means for communicating with other people (letters, telegrams, telephones, etc.), so you have various ways to communicate with the computer. The major ways are described below:

Punched cards. Punched cards have many uses, such as college registration cards, electricity bills, and payroll data. They are cheap and versatile. The standard punched card is called a Hollerith card after Dr. Herman Hollerith who, as head of the U.S. Census Bureau's tabulating section, invented punched cards to help with the 1890 census. The 1880 census had taken seven years to complete and Dr. Hollerith feared that, due to the growing population, the 1890 census might not be finished in time to start the next census in 1900. Thanks to punched cards and card tabulating machines (not computers) the 1890 census was completed in less than three years.

The standard punched card has 80 vertical columns and can hold 80 characters of information (letters, numbers, or punctuation).

In the Hollerith punching system, one punch in a single column (number row) can represent any number from 0 to 9. Above the nine number rows are three zone rows: 0, 11 and 12. By making two punches in a single column — one in a zone row and the other in a number row, it is possible to represent any letter of the alphabet. Certain special characters can be represented by three punches in a single column. A period is represented by a 12 punch, a 3 punch and an 8 punch. A dollar sign is represented by an 11 punch, a 3 punch and an 8 punch. The card shown contains punches for the alphabet followed by punches for numbers 0 through 9. Keep in mind that Hollerith symbolic language must be translated (it's done automatically) into binary to be used by a computer.

Punched paper tape. Punched tape is cheap and easily stored in rolls. Some kinds of business machines, including typewriters and cash registers, can be equipped to automatically punch paper tape as they are used in normal business. The resulting records can be easily fed into computers for further processing.

Magnetic tape. Two major advantages make magnetic tape the main recording medium for computer data. It can hold huge quantities of data—a single 10½ inch reel of tape can hold the contents of 250,000 punched cards — and magnetic tape can be read with lightning speed. Some computers can read up to 120,000 characters a second from magnetic tape, compared with only 1,200 characters a second from punched cards.

Rolls of magnetic tape serve as the computer's external memory, just as books serve as a person's external memory. Both provide information as needed. In working many problems computers require both fresh data and stored data. In doing a payroll, for example, the fresh information probably would be fed into the computer from punched cards or paper tape. In addition, the computer would need certain basic facts, such as the employee's rate of pay, income tax deductions and so forth. This information would be kept on magnetic tape to be fed into the computer's internal memory as needed.

The magnetic tape used in a computer system is similar to the kind used in a home recorder. It is a plastic ribbon with an iron oxide coating that can be magnetized. A tiny area of oxide is magnetized to indicate a 1 in binary code; a blank area in the pattern stands for zero. A pattern of symbols is arranged in vertical columns on the tape, just as holes are punched on a paper tape. One advantage of magnetic tape is that its pattern of symbols almost always is in "pure binary" and can be read directly by the computer. The code punched into paper tape may be punched in binary. Or it may use a special code of its own, as is the case with some telegraph punching equipment. The illustration at the left shows what the magnetized spots on magnetic tape would look like, if you could see them. Like tape used on a home recorder, computer magnetic tape can be easily erased and reused.

Magnetic discs. In place of external memory units using magnetic tape, some computer systems use magnetic discs. The discs, which look something like big phonograph records, can make information available to the computer more quickly than tape.

Magnetic ink. Documents printed with magnetic ink are "read" in much the same way magnetic tape is read. The additional advantage of magnetic ink characters, which were developed by General Electric, is that they can be read by people, as well as by computers. Today banks make wide use of magnetic ink characters, particularly on checks.

Optical scanners. If all numbers and words, not just those printed in magnetic ink, could be read by computers, it would save much of the bother of translating information into special codes for computer input. The computer industry is working toward this kind of versatility. An optical scanner has a set of electronic patterns in its memory and a photoelectric cell that scans material to be read, converting characters into electronic pulses. The scanner can "read" any character that matches the patterns stored in its memory.

High-speed printing. This is the most important medium for getting information out of the computer. A high-speed printer whips out information at as much as 1200 lines a single minute. For you to turn out 1200 lines, typing 60 words a minute on a typewriter, would take eight hours. Types of information turned out by this printer include accounting forms, checks, and department store bills.

Typewriter. As part of their control unit, most computers have an elec-

tric typewriter. Through it the human operator can enter information directly into the computer. Also, he can receive through the typewriter short answers to problems worked by the computer. If there is a programming error, the computer may type out information that enables the human operator to make a correction.

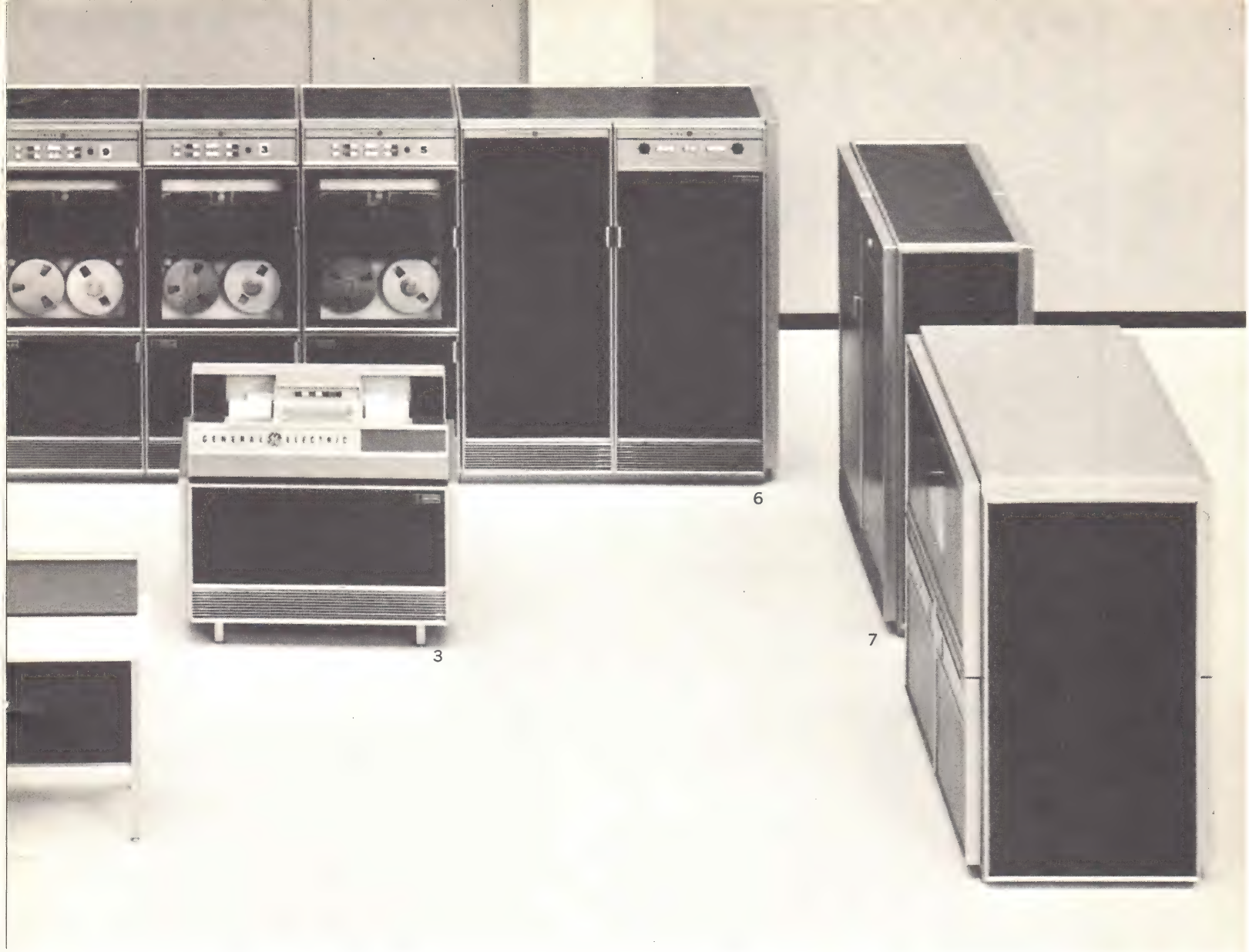
Display lights. Some computers have a section of lights that can instantly show what information is in control, memory and the arithmetic section. The display is in binary; if a light is on, it is a 1; if it is off, it is a 0.

Cathode ray tube. Some kinds of scientific problems worked by computers have answers that are in curves and other lines. While these answers can be printed, it is sometimes more convenient to translate the information into an image that is flashed on a cathode ray tube, similar to a TV screen. The human operator may learn what he needs simply by looking at the image. Or, for future reference, he may photograph the pattern.

COMPUTER HARDWARE

Equipment that makes up a computer system is called hardware. There are two categories of hardware: The central processor that is the actual computer, containing memory, control, and arithmetic units, and a variety of supporting equipment called peripherals.

All you need for a computer system is a central processor and at least one type of equipment to get information in and out of it. Generally speaking, the more kinds of



peripheral equipment you have, the more kinds of jobs you can do. The computer system shown here is manufactured by General Electric as part of its Compatibles/400 line. The equipment is described below:

Central processor

1. GE-415 Central Processor — the actual computer. It contains a solid core memory, an arithmetic unit, and control circuits. With no moving parts, it operates at nearly the speed of light.

2. Console — comparable to an airplane's cockpit. The console has controls that enable the human operator to run the computer system. It has lights, switches, and a typewriter. Through the typewriter the operator sends information into the computer and receives answers out.

Peripherals

3. Card reader — reads standard 80-column cards column by column. As it reads, the information is automatically translated into the binary language of the computer.

4. Card punch — punches 80-column cards at 100 cards per minute. After punching it reads the cards to check for accuracy.

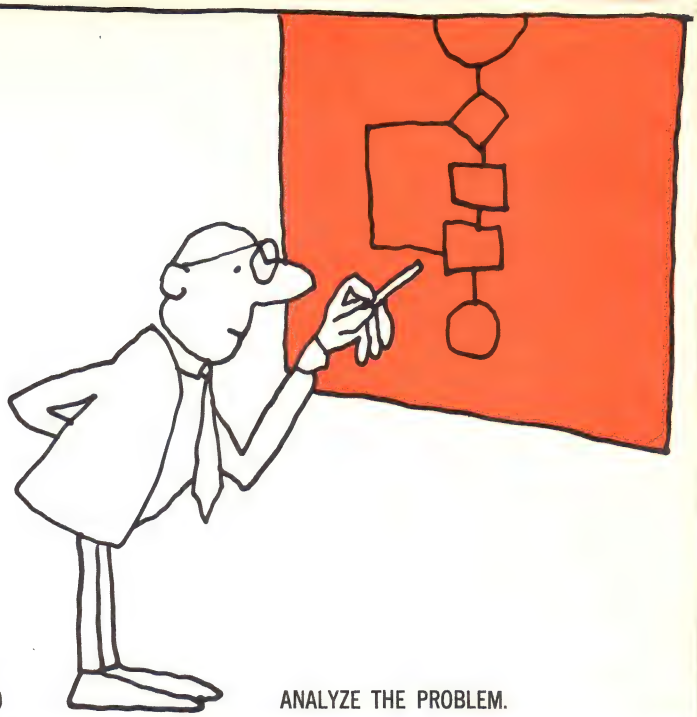
5. High-speed printer — turns out 1200 lines a minute. Unlike a typewriter, it prints an entire 136-character line at once, rather than one character at a time.

6. Magnetic tape units — the computer's external memory — feed information into the internal memory in the central processor as needed.

7. Disc storage unit — another external memory unit. It stores information on magnetic discs for fast delivery to central processor.

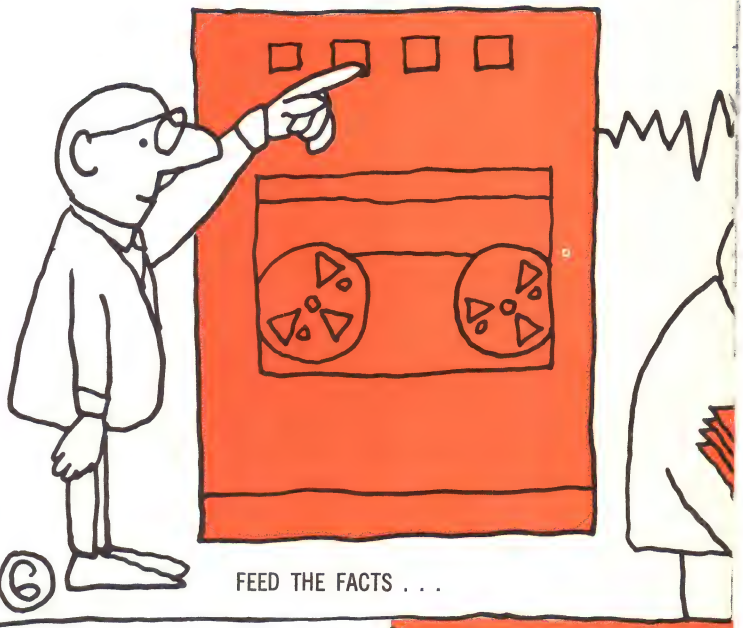
Solving a Problem

1



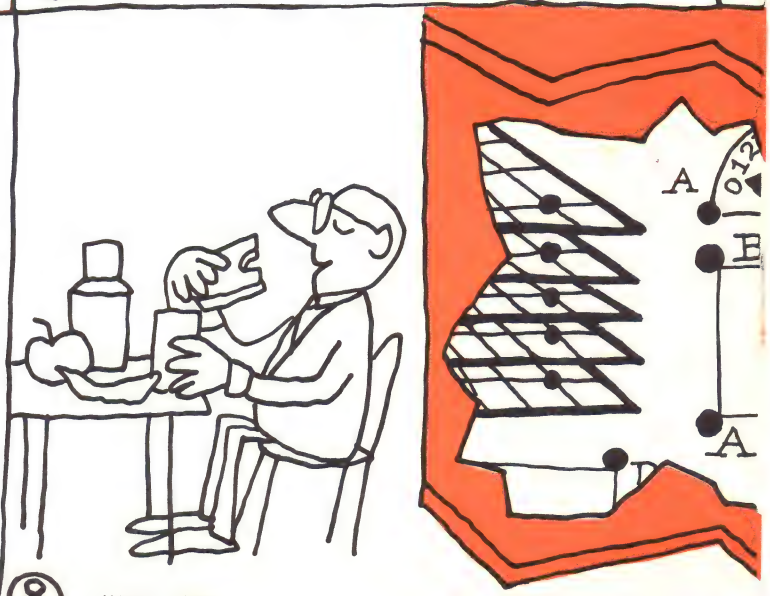
2 ANALYZE THE PROBLEM.

5 GATHER FACTS; PUT ON MAGNETIC TAPE.



6 FEED THE FACTS . . .

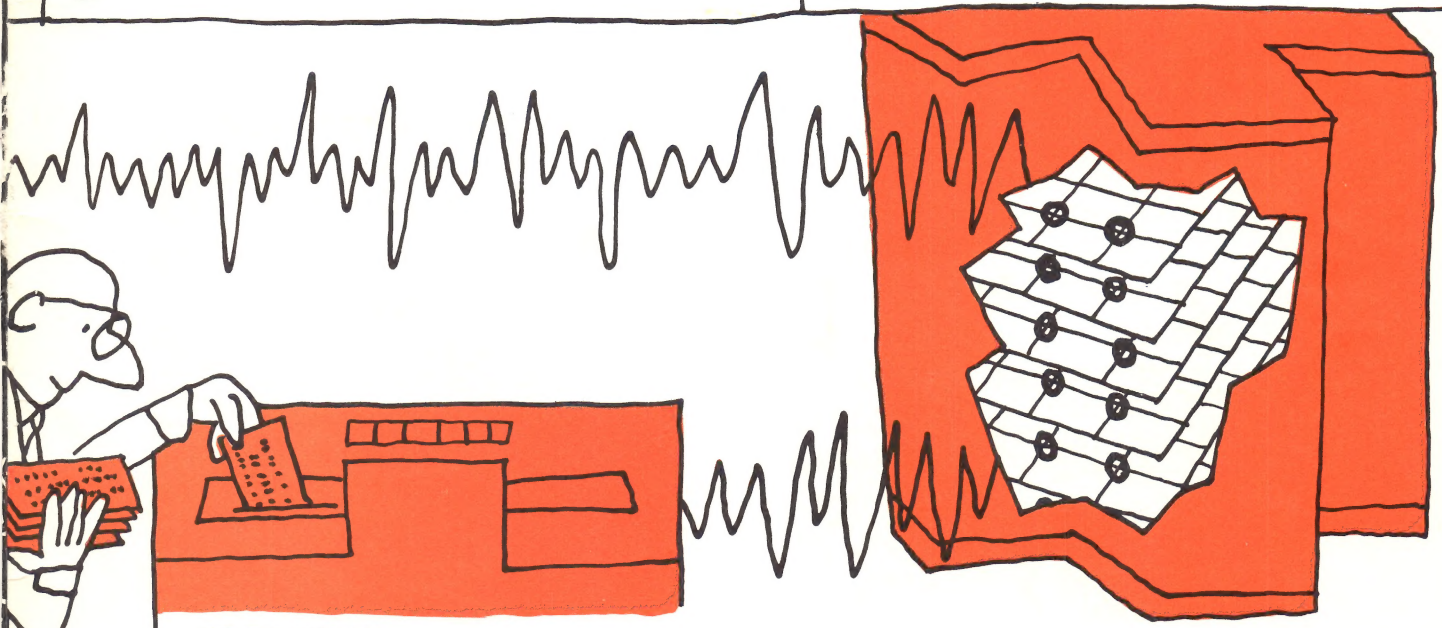
7 START THE COMPUTER.



8 HAVE LUNCH.

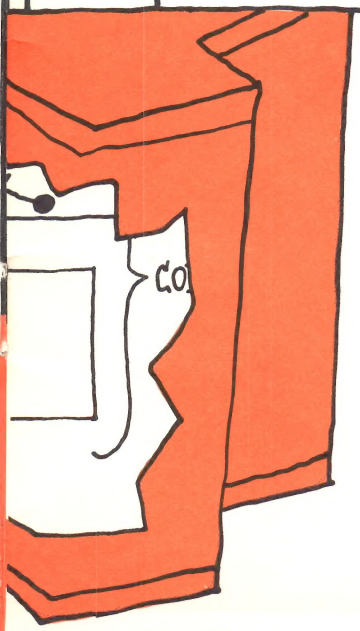
3 WRITE A PROGRAM.

4 PUNCH PROGRAM INTO CARDS.

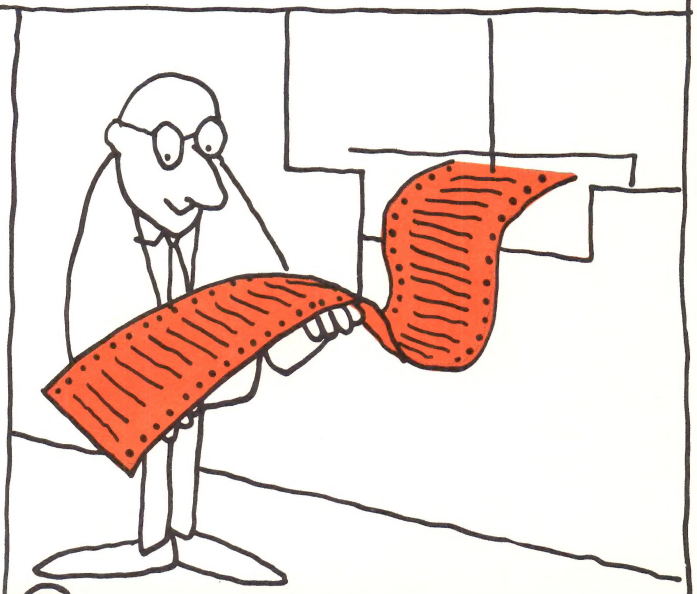


AND THE PROGRAM . . .

INTO THE CENTRAL PROCESSOR'S MEMORY.



NOW THE COMPUTER TAKES OVER. IN THE CENTRAL PROCESSOR IT FOLLOWS EACH INSTRUCTION IN SEQUENCE. BY OPENING AND CLOSING SWITCHES, IT MOVES ELECTRONIC PULSES REPRESENTING DATA IN AND OUT OF THE ARITHMETIC SECTION. THE COMPUTER WORKS AUTOMATICALLY UNTIL THE PROBLEM IS SOLVED.



9 READ THE ANSWER.

West Point cadets learn to use computers in their first week of class.

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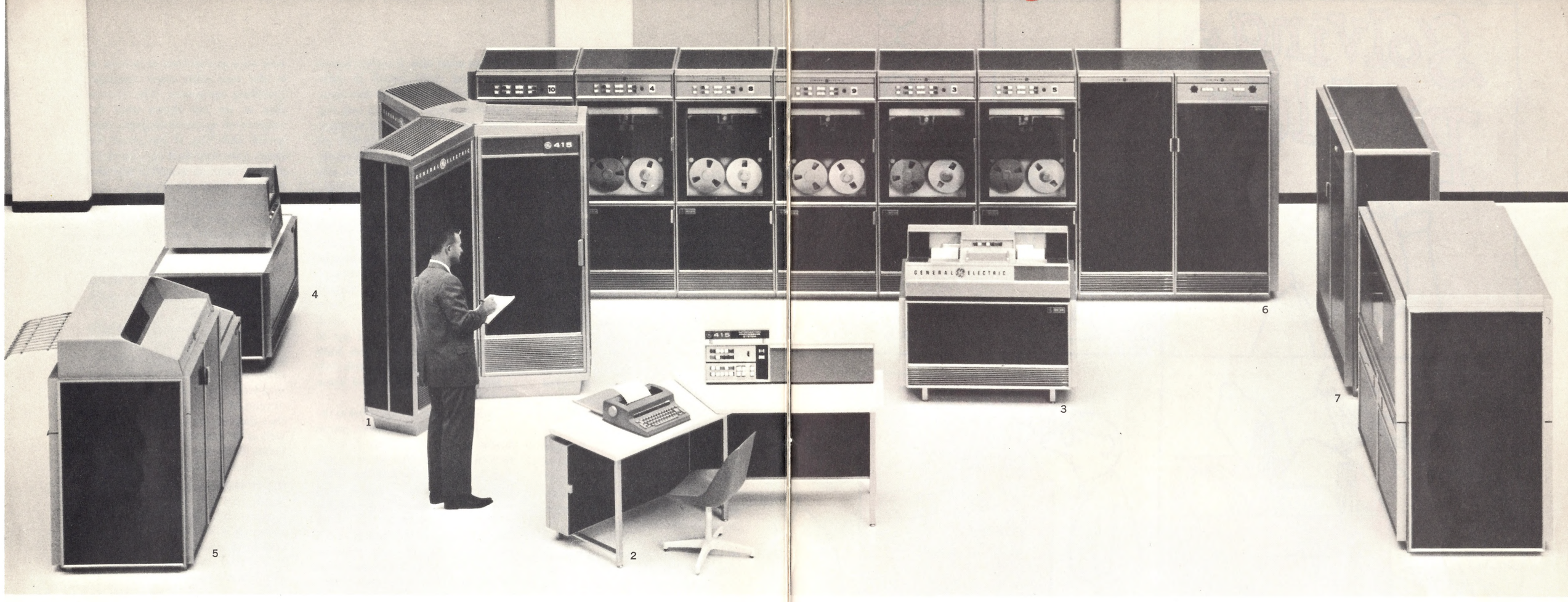
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GENERAL ELECTRIC
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